Astronomy & Astrophysics manuscript no. N3610˙TEST˙M32˙2ND
August 6, 2010

Research Note

The mid-UV population of the nucleus and the bulk of the post-merger NGC 3610

L.M. Buson

INAF Osservatorio Astronomico di Padova, vicolo dell'Osservatorio 5, I-35122 Padova, Italy
e-mail: lucio.buson@oapd.inaf.it

Received ... ; accepted 2010

ABSTRACT

Context. The very center (r≪r_e) of NGC 3610, a clearly disturbed giant elliptical generally assumed to be a post-merger remnant, appears dominated in the mid-UV (2500-3200 Å spectral region) by a stellar population markedly different from that dominating the bulk of its stellar body.

Aims. I want to make use of the mid-UV spectra of NGC 3610 as seen through tiny (∼1") and large (10"×20") apertures as a diagnostic population tool.

Methods. I compare archive IUE/LWP large aperture and HST/FOS UV data of NGC 3610.

Results. The strength of mid-UV triplet (dominated by the turnoff population) shows a remarkable drop when switching from the galaxy central arcsec (FOS aperture) to an aperture size comparable to ∼0.5 r_e (IUE).

Conclusions. The sub-arsec (mid)-UV properties of this galaxy involved in a past merger reveal a central metal enrichment which left intact the bulk of its pre-existing population.

Key words. galaxies: general — galaxies: elliptical and lenticular, cD — galaxies: individual: NGC 3610 — galaxies: interactions

1. Introduction

The E5 galaxy NGC 3610 appears peculiar in many respects. It has the richest fine structure of all ellipticals discussed by Seitzer & Schweizer (1990), as well as a warped central disk identified by Scorza & Bender (1990) by means of their photometric decomposition and later confirmed by means of HST by Whitmore *et al.* (1997). In addition, its anomalous (B-V) color (e.g. Goudfrooij et al. 1994) is an indicator of recent star formation. At the same time the galaxy is encircled by a globular cluster (GC) system showing evidence of a past merger of metal-rich disk-disk galaxies (Goudfrooij et al. 2007).

Send offprint requests to: Lucio M. Buson

Since the epoch of the major merger which formed NGC 3610 is estimated to be 4 ± 2.5 Gyr ago (Strader et al. 2004), this makes it an ideal galaxy for studying this kind of phenomenon, including the so-called “formation by merger” scenario for metal-rich GCs (Schweizer 1987; Ashman & Zepf 1992). Such galaxies, though having reached a substantial dynamical equilibrium, are indeed still young enough to keep track, both morphological and evolutionary, of the past interaction.

In fact, though the most exhaustive, up-to-date study of the age, metallicity and α-enhancement gradients within NGC 3610 of Howell et al. (2004) does not find significant stellar population gradients in the outer parts of the galaxy ($r \geq 0.75\ r_e$), a clear indication of the presence of a *central* young stellar population in NGC 3610 has been pointed out by Silva & Bothun (1998) on the basis of the strong central Hβ absorption in the optical and the IR excess Δ(H-K) between ($r \leq 0.5$ kpc $= 0.25\ r_e$) and the outer annulus ($1.0 \leq r \leq 1.5$ kpc) induced by the presence of intermediate-age AGB stars. Silva & Bothun (1998) refer also to a central, subarcsec UV HST/FOS spectrum of the galaxy they put forward as a proof of intermediate-age nuclear stars, being well-matched by a mid-F main-sequence stellar population very similar to that of M32.

Luckily enough the existing (archive), space-borne ultraviolet data include also a good-quality UV spectrum of the galaxy through the large (10×20”) IUE/LWP aperture giving the luminosity-averaged spectral energy distribution (SED) within an aperture photometrically equivalent to an aperture 7” in radius (cf. Burstein et al. 1988). Since the two UV spectra, especially as far as the region of the absorption lines formed by the Mg II 2800 Å, Mg I 2852 Å and the Fe I + II + Cr I feature at 2750 Å (the so-called UV triplet, well-known for showing rapid changes in relative strengths from late B to late F stars) is concerned, appear quite different (see Fig. 1), one can expect their comparison represents a further proof of the different nature of the galaxy’s inner and large-aperture stellar population.

2. UV observations

A good-quality (15,300 s exposure time) IUE/LWP spectrum of NGC 3610 has been obtained in 1992 at GSFC by LB. The orientation of the IUE large aperture was P.A.=154°. As stressed above its ″oval″ (10″×20″) shape is photometrically equivalent to a 7″ radius circular aperture (*cf.* Burstein *et al.* 1988), *i.e.* $\sim 0.5\ r_e$ in the case of NGC 3610 (Idiart *et al.* 2003). As in the case of NGC 5018 (Bertola *et al.* 1993), a IUE/SWP spectrum shortward of λ 1800 Å provided no signal, thus implying that also NGC 3610 lacks the prominent UV-upturn typical of old, metal-rich giant spheroids.

Almost simultaneously NGC 3610 was observed with the HST/FOS on 1992 November 30. A FOS circular aperture 0″.86 diameter has been used. The target acquisition procedure involved measuring the flux on a 4×4 grid at 0″.25 intervals so as to center the galaxy to an accuracy of 0″.25. The datum I use here is the mid-UV FOS/G270H spectrum.

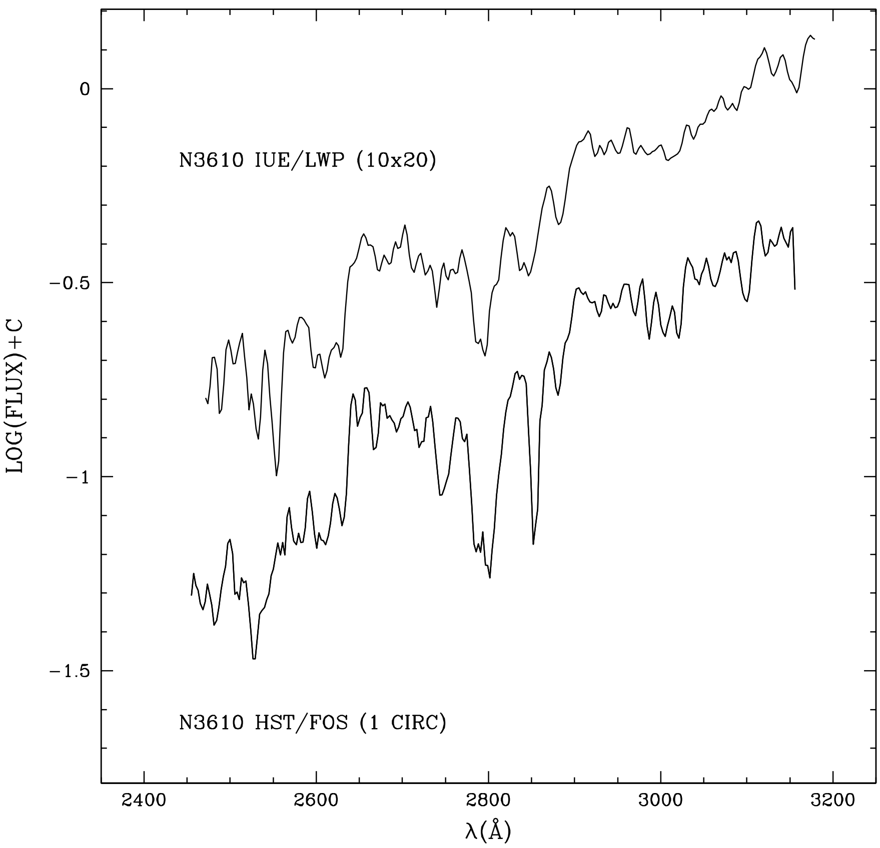

Fig. 1. Comparison of the IUE /LWP (10″×20″) spectrum of NGC 3610 and its ~1″ circular central HST/FOS G270H spectrum. Note the outstanding difference of the mid-UV triplet between the two spectra of the same object. All plots are given in log F_{λ}+C. The HST/FOS G270H spectrum has been properly smoothed to match the IUE/LWP spectral resolution (about 6-7 Å about λ 2,700 Å). An arbitrary shift has been finally applied for showing purposes.

The properly extracted, redshift-corrected IUE and HST/FOS mid-UV spectra of NGC 3610 are shown on a logarithmic scale in Fig. 1 (they are properly shifted for showing purposes) after a proper resolution match of the original data. Following both Burstein & Heiles (1984) and Schlegel et al. (1998), NGC 3610 is galactic extinction-free and no correction has been applied. A quantitative comparison of commonly used mid-UV indices is instead given in Tab. 1 for both apertures. The same set of indices is given also for the center of M32 for comparison with an intermediate-age population.

NGC 3610 has not been observed by the GALEX satellite yet, thus hampering the possibility of a useful comparison of its optical metallicity gradient with an extended ultraviolet color (FUV−NUV) profile.

Table 1. IUE vs. FOS Mid-UV Indices

Feature	N3610/IUE mag	N3610/FOS mag	M32/FOS mag
MgWide	0.351±0.017	0.370±0.007	0.285±0.002
FeI+II+CrI	0.082±0.050	0.188±0.018	0.351±0.010
MgII2800	0.442±0.047	0.756±0.018	0.795±0.014
MgI2852	0.237±0.046	0.456±0.017	0.349±0.008
FeI3000	0.106±0.040	0.208±0.013	0.199±0.003
2828/2921	0.561±0.028	0.577±0.011	0.510±0.005

3. Mid-UV indices as a population diagnostic tool

From Fig 1 it is immediately recognizable that the FOS (central) spectrum shows a much deeper mid-UV triplet close to λ 2800 Å which reflects in the indices of Tab. 1 computed following the definition of Chavez et al. (2007). As far as the index measurements are concerned, it is well known that IUE cameras (and thus extracted spectra) are potentially affected by the camera reseau marks. Luckily enough I verified that the LWP camera artifacts do not affect the mid-UV indices I made use of in this paper (from Fig. 2 one can see that neither the red bandpass of the index FeI3000 (ending at λ 3051 Å) turns out to be influenced).

A careful analysis of the indices listed in Table 1 does suggest the following picture for the chemistry/age pattern of the center and bulk of NGC 3610, as well as for the comparison object M32: (i) on the basis of the doubling of the main iron and magnesium indices like FeI+II+CrI, FeI3000, MgII2800 and MgI2852 the central regions (within the FOS aperture) of NGC 3610 appear systematically more metal rich (when compared with the large IUE region) and—**assuming that the metallicity of the (central) population is approximately solar (cf. Fig 4 in Howell et al. 2004)**—younger than 4 Gyr (cf. Fig. 2 of Chavez et al. 2009); (ii) The nucleus of NGC 3610 appears quite α-enhanced in comparison with that of M32 taking into account, e.g., the much lower value of the iron index FeI+II+CrI and the slight increase of the MgWide index (cf. Fig. 5 of Chavez et al. 2009).

4. Comparison with NGC 5018

A similar analysis, namely IUE Large Aperture vs. FOS, has been adopted by Buson et al. (2004) for NGC 5018, an object with many similarities with NGC 3610 (e.g. a major merger suffered ~3 Gyr ago [Leonardi & Worthey 2000]). However, unlike NGC 3610, the stellar population of NGC 5018 tells a simple story, in the sense that it shows both a strict match of its IUE and HST/FOS circumnuclear spectrum and quite a shallow metallicity gradient, as traced by Mg_2 index (dMg_2/dlogr=-0.04; Carollo & Danziger 1994). In other words, its population is very homogeneous, both in age and metal content (as expected to occur if the merger is largely dissipationless) and/or suffered from a rejuvenation involving the whole galaxy.

In this respect NGC 3610 could instead represent a different kind of merger, especially taking into account that its inner mean gradient decreases at a rate of [Z/H]=-0.30 per decade in

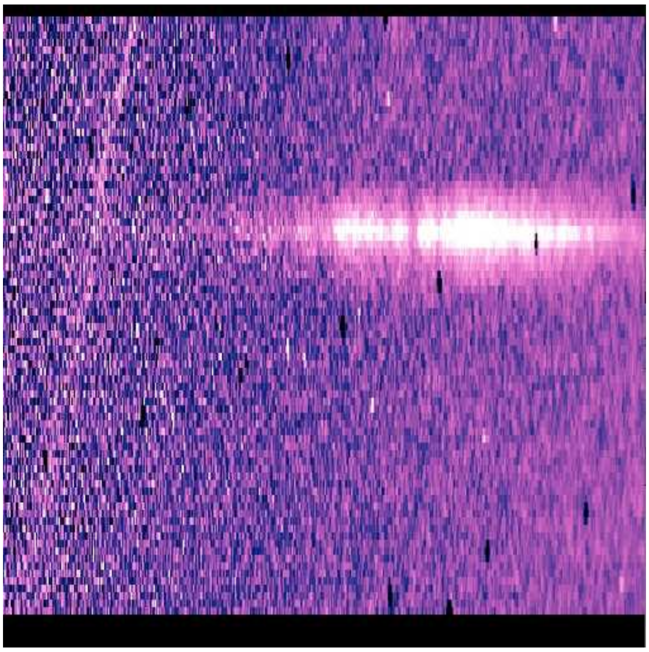

Fig. 2. IUE /LWP10105 spectrum of M32 shown here for showing purposes (i.e. to give the right localization of the camera reseau marks). As can be seen the spectral regions corresponding to the indices used here are free from reseau contamination.

r/r$_e$ (Howell et al. 2004). The onset of such a gradient, though not unexpected during a dissipative galaxy merger (e,g. Barnes & Hernquist 1991; Mihos & Hernquist 1994; Kobayashi 2004), represents unequivocally a population unhomogeneity. Moreover, its stronger absorption mid-UV spectrum appears confined to its very center alone. **The natural conclusion is that the central arcsec in NGC 3610 underwent significantly more rejuvenation and/or metal enrichment than its surroundings, unlike NGC 5018.**

Acknowledgements. It is a pleasure to thank Sandro Bressan—largely experienced in mid-UV indices modeling—for useful discussions. I thank the anonymous referee for his/her comments improving this paper.

References

Ashman, K. M., & Zepf, S. E. 1992, ApJ, 384, 50

Barnes, J. E., & Hernquist, L. E. 1991, ApJ, 370, L65

Bertola, F., Burstein, D., & Buson, L. M. 1993, ApJ, 403 573

Burstein, D., Bertola, F., Buson, L.M., Faber, S.M., & Lauer, T.R. 1988, ApJ, 328 440

Burstein, D., & Heiles, C. 1984, ApJS, 54 33

Buson, L.M., Bertola, F., Bressan, A., Burstein, D., & Cappellari, M. 2004, A&A, 423, 965

Carollo, C.M., & Danziger, I.J. 1994, MNRAS, 270 743

Chavez, M., Bertone, E., Buzzoni, A., Franchini, M., Malagnini, M.L., Morossi, C., & Rodriguez-Merino, L.H. 2007, ApJ, 657 1046

Chavez, M., Bertone, E., Morales-Hernandez, J., & Bressan, A. 2009, ApJ, 700, 694

Denicolò, G., Terlevich, R., Terlevich, E., Forbes, D. A. & Terlevich, A. 2005, MNRAS, 358, 813

Dorman, B., O'Connell, R.-W., & Rood, R.-T. 2003, ApJ, 591, 878

Goudfrooij, P., Hansen, L., Jorgensen, H. E., et al. 1994, A&AS, 104 179

Goudfrooij, Paul, Schweizer, F. Gilmore, D., Whitmore, B.C. 2007, AJ, 133, 2737

Howell, J. H., Brodie, J. P., Strader, J. Forbes, D. A. & Proctor, R. 2004, AJ, 128, 2749

Idiart, T.P., Michard, R. & de Freitas Pacheco, J.A. 2003 A&A, 398, 949

Kobayashi, C. 2004, MNRAS, 347, 740

Leonardi, A.J., & Worthey, G. 2000, ApJ, 534 650

Mihos, J. C., & Hernquist, L. 1994, ApJ, 437, L47

Rose, J.R. & Deng, S. 1999, AJ, 117, 2213

Schlegel, D.J., Finkbeiner, D.P., & Davis, M. 1998, ApJ, 500 525

Schweizer, F. 1987, Nearly Normal Galaxies. From the Planck Time to the Present, 18

Scorza, C., & Bender, R. 1990, A&A, 235, 49

Seitzer, P., & Schweizer, F. 1990, in Dynamics and Interactions of Galaxies, ed. R. Wielen (New York: Springer), 270

Silva, D.R., & Bothun, G.D. 1998, AJ, 116 2793

Strader, J., Brodie, J. P., & Forbes, D. A. 2004, AJ, 127, 295

Whitmore, B. C., Miller, B. W., Schweizer, F. & Fall, S. M. 1997, AJ, 114, 1797